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The Importance of the Points of Contact in Electric Injuries

Physical Impairment among One Thousand Negro Factory Workers

Cardiovascular Impairment among One Thousand Negro Factory Workers

The International Silicosis Conference Held at Johannesburg, August, 1930

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THE JOURNAL OF INDUSTRIAL HYGIENE

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THE IMPORTANCE OF THE POINTS OF CONTACT IN ELECTRIC INJURIES*

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INTRODUCTION

THERE are numbers of factors that must be considered in dealing experimentally with the problem of the damage to the organism produced by an electric current. Among these are the voltage of the circuit, resistance at the contacts, relative resistance of different tissues to the flow of current, and the total current that flows through the body. The duration of the contact is extremely important, as has been demonstrated in previous experiments.

The location of the contacts determines to a large extent the pathway of the current through the body. Assuming the specific resistance of the body as uniform, the current in its passage extends out in a fusiform shape but it is difficult to believe that the current density in parts remote from the main pathway is high. Thus, if the contacts in man are made with one arm and the leg of the same side, it scarcely seems possible that a great amount of current would pass through the head. Since the brain appears to be relatively easily injured by electricity, one electrode in legal electrocution is placed upon the skull.

In industrial accidents, on the other hand, the current seldom traverses the head directly. Maclachlan (1), in an analysis of 479 cases of human accident, found that the pathway of the current through the body was approximately the same, owing to the very routine of the work carried out by the men. The workmen were liable to contact with the hands or the arms. Either they were standing on the ground or their feet made contact with ground wires so that the current traveled through the trunk to the legs.

It is the common belief among students of electric accidents that unconsciousness and death from high poten-

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tial contacts are due to a paralysis of the respiratory center in the medulla. Accordingly experimental investigators have endeavored to reproduce the damage in the brain by causing the current to pass directly through it. Urquhart (2) first applied one electrode over the occiput and the other upon a hind leg. In this case there was some possibility that the heart might have been damaged. Therefore in another series of experiments the current was allowed to traverse the head alone; one of the electrodes was placed far back in the nasal cavity and the other on the atloido-occipital ligament.

The present authors, in their previous studies (3), were also interested in the damage produced in the central nervous system by electricity. They chose as an experimental animal the rat; in this small mammal no ventricular fibrillation of the heart is produced by the passage of the current and it is believed that none of the animals died of cardiac failure. In almost all these experiments one electrode was fastened to the dorsal surface of the skull; the other made contact with the tail. Under these conditions it is thought that considerable electricity passed through the brain. Gross and microscopic hemorrhages occurred in the central nervous system and marked damage to the nerve cells was found. These have been described in previous papers (4) (5).

The question arose as to whether the pathway of the current through the body was not an important factor in determining the extent of the trauma. Are injuries to nerve cells in the brain stem produced when the current does not pass directly through the head? It is hoped that these problems may be settled by investigations already under way.

Langworthy (6) reported the nerve cell injuries in two cases of human electrocution. One of these two cases was legally electrocuted and the current passed through the head. The other made contact with an electric circuit at 2,200 volts through the arms and feet, the period of contact being long enough to produce severe burns. In both cases marked nerve cell injury occurred. The period of contact in the second case was so long that the nerve cell changes may have been due entirely to heating. Nerve cell changes are not specific for different types of injurious agents. It also may be possible that the pathway of electricity in the body is influenced to some degree by fluid columns, for example, by the blood in the arteries.

The present series of experiments, utilizing 102 rats, was devised to test the importance of the pathway of the current through the body. Half of the series were subjected to an alternating circuit, the other half to a continuous; the potential of the circuit was kept constant at 1,000 volts. In all cases the duration of the shock was two seconds. The amount of current flowing in each experiment is recorded in amperes. In all the experiments by the present authors it has seemed important to deal with a constant potential rather than with a constant amperage, since in industrial accidents the potential of the circuit is the known factor. The electrodes were then attached to different portions of the body. The first group was subjected to the current with the electrodes on the head and tail, in order to correlate the present work with experiments

already published. The other combinations of electrical contacts were the following: right foreleg and tail; left foreleg and tail; right foreleg and left foreleg; right hind leg and left hind leg; right foreleg and left hind leg; and finally left foreleg and left hind leg.

Methods

The general technic of the experiments has already been published. The 1,000-volt alternating current was furnished by a step-up transformer with a ratio of 1 to 10. The frequency of the current was 60 cycles. The primary voltage was obtained from a special alternator driven at constant speed, and its value was controlled by adjusting the magnetic field of the alternator. The 1,000 continuous circuit voltage was taken from a 1,000-volt generator with a separately excited field. A separate switch was used to close the circuit in which the animal was placed. Time was measured with a stop watch.

Preparatory to the shock, the rats were given ether until they were quiet. The areas where the electrodes were applied were thoroughly moistened with saline solution. Metal clips were used for contact with the legs or the tail. The head electrode fitted snugly and made contact only over the dorsal surface of the skull.

Attempts at artificial respiration are rather unsatisfactory in such a small animal. They consisted in digital pressure upon the chest, reproducing as far as possible the Schäfer method in man, pulling out the tongue, stimulating the vagus nerves in the neck with the fingers, and efforts to keep the respiratory tract free from mucus.

Observations

The results will first be discussed under topical headings. The experiments are grouped on the basis of the type of circuit and the position of the electrodes upon the surface of the body.

Electrodes Applied to Head and Tail

Alternating Circuit.—Six rats in the present series were subjected to an alternating current circuit with the electrodes applied to the head and tail. Two of the rats were normal following the shock, one was paralyzed, and three died at once without breathing. In all of the latter the heart beat strongly for a considerable period. The current readings were from 0.7 to 0.84 amperes.

Immediately following the shock there were marked clonic movements of all the musculature of the body, which continued for a period of minutes. These movements may be due to a marked stimulation of the motor cells in the nervous system by the current or, what is more likely, to the increased carbon dioxide in the blood following the shock in the period before adequate respiratory movements are resumed. Graham Brown has shown that under suitable conditions, motor cells in the spinal cord may be stimulated to activity by substances in the blood stream after the manner of the respiratory center.

When rats are shocked with the alternating circuit the chest is fixed in maximal expansion, and adduction of the vocal cords prevents the escape of air from the lungs for several seconds after the current ceases to flow. This seems to be an important aid to the

resumption of spontaneous respiration or to adequate artificial respiration. After continuous current contacts, the chest is completely collapsed and it is impossible to force any air into the chest.

With the alternating circuit injuries, emission occurred almost constantly in the males. This is thought to be due to the powerful contraction of all the musculature of the body produced by the current.

Paralyses were less common in this whole series of animals injured with the alternating circuit than in the series previously described, and gross hemorrhages and degenerations of the spinal cord were less frequent. No explanation for this discrepancy can be given.

Artificial respiration was used on all these rats for a considerable period before they breathed spontaneously. Even after breathing was established it was shallow, fast, and irregular for a period of hours following the contact. This was true of the rats that later were quite normal.

The results recorded here may be compared with those obtained in the previous experiments. Ten rats were shocked with alternating 1,000-volt circuit for two seconds with the contacts applied to the head and tail, fulfilling all the requirements of the present series. The current readings were from 0.65 to 1 ampere. Three of the rats recovered, five were paralyzed, and two died at once. Autopsy showed that the surface of the cerebral cortex was burned in three, the skull injured in another, and there was an abscess in the forebrain of the third. The results in the present group may, therefore, be correlated exactly with the experiments previously published.

Continuous Circuit.—It was found that no rats in the previous series survived a contact of one second or over with a 1,000-volt continuous circuit when the electrodes were applied to the head and tail. In these cases the current readings were from 0.6 to 1.1 amperes. The contact was made for approximately one-half second in ten animals; five died at once, two were paralyzed, and two recovered from the immediate effects of the shock.

Since these results were known, only three rats in the present group were subjected to a continuous circuit with the electrodes applied to the head and tail. The contraction of the musculature during the shock was not so great as in the group shocked with the alternating circuit, and no clonic contractions of the musculature followed breaking of the contact. Artificial respiration was used; the chest was collapsed following the shock. One of the rats responded with a few respiratory efforts but did not breathe spontaneously. The heart beat in each case for a period following the shock.

The results show how damaging the 1,000-volt continuous circuit is, when applied to rats through electrodes attached to the head and tail. Few abnormalities were found at autopsy but microscopic examination showed severe injury of the nerve cells.

Electrodes Applied to Right Foreleg and Tail

Alternating Circuit.—In these experiments one electrode was applied to the right shoulder and another to the tail. The twelve rats in this series were subjected to a 1,000-volt alternating circuit for two seconds. The current readings were from 0.6 to 0.84 am-

peres. The average weight of the rats was 178 gm. The rats were hyperirritable to all sensory stimuli for several minutes following the shock and showed the clonic twitchings of the musculature already described. Five of the animals began to breathe spontaneously very soon after the circuit was opened; artificial respiration was used in the case of the others. One rat never breathed following the injury; three others breathed for a few seconds or minutes; and another lived for four hours. Five rats died soon after the shock, three were paralyzed, and four recovered completely.

Artificial respiration was used for a considerable period in the case of many of the animals before normal breathing was initiated. Moreover, the rats were not necessarily on the road to recovery when breathing had once begun. This has been mentioned in the case of human accidents and should be emphasized in any thesis dealing with the treatment of industrial injuries. Three of the animals in which breathing had once been initiated died from respiratory failure, and a fourth died at the end of four hours. Another animal was made to breathe by a second application of artificial respiration. Many of the animals breathed in a fast, shallow, and irregular manner for a number of hours. Emissions occurred in practically all the males. Bleeding was evident in many cases from capillary hemorrhages in the conjunctivae. The results in this series differ little from the alternating group at 1,000 volts in which the path of the current ran from head to tail.

Continuous Circuit.—Twelve rats were shocked with the 1,000-volt continuous circuit with the electrodes applied to the right foreleg and the tail. The current readings were from 0.5 to 1 ampere. The average weight of the rats was 105.6 gm. Six of the rats breathed as soon as the contact was broken; the others were given artificial respiration. One of these rats, a very small one weighing only 68 gm., made only a few efforts at breathing, and died. A second stopped breathing after normal respirations had been initiated, and died. A third breathed with great difficulty. Of the twelve rats, two died at once, one died within a few minutes, four showed paralyzed hind legs, and five recovered from the immediate effect of the trauma.

The paralyzed hind legs in this group were not due to injury of the spinal cord but to burning of the legs near the tail electrode. Indeed the burns were much more severe than in the alternating circuit series.

Discussion.—The animals shocked from the two types of circuits with the electrodes applied to the right foreleg and the tail may now be compared. In the alternating group 33 per cent. recovered as compared with 42 per cent. in the continuous circuit group. These results do not tell the whole story. The burns were much more severe in the continuous series and these injuries made it impossible for any of the animals that survived the initial shock to live permanently. The animals are so small that extensive burns produced injury of vital areas in all cases, and no rat could be kept alive for over three days. On the other hand, the rats that recovered from the shock from the alternating circuit without paralysis lived for an

indefinite period and seemed quite healthy when they were killed for postmortem examination.

No rats survived the continuous circuit shock when the duration of the contact was one second or more, with the electrodes applied to the head and tail. The survival of 42 per cent. following a contact for two seconds when the electrodes were placed on the foreleg and the tail, suggests that more animals survive the immediate shock when the brain is not included in the path of the current.

Electrodes Applied to Left Foreleg and Tail

Alternating Circuit.—Twelve rats were subjected to the 1,000-volt alternating circuit, the current traveling from the left foreleg to the tail. The current was from 0.62 to 0.9 amperes. Three animals breathed at once; the remainder were given artificial respiration. Two rats never breathed and a third stopped within an hour. Two other rats were paralyzed. In this group, three, or 25 per cent., died; two, or 17 per cent., were paralyzed; and seven, or 58 per cent., recovered from the shock. The abnormalities in these animals were similar to those previously described. There was bleeding in the conjunctival mucous membrane in several, and in one rat considerable frothy fluid came from the mouth. Emissions occurred in the males. One other rat died after four hours. Most of the animals that survived the initial trauma without paralysis made a complete recovery. As described in a previous paper, the rats were quiet for forty-eight hours following the injury and refused food and fluids during that time.

There was very little difference in the injury produced by the alternating current when the pathway was from left foreleg to tail from that produced when the pathway was from right foreleg to tail. When the right foreleg formed one contact the recovery was 33 per cent., and when the left foreleg formed one contact the recovery was 58 per cent.; the latter was slightly less dangerous to life.

Continuous Circuit.—Again, twelve rats were shocked with the continuous 1,000-volt circuit, the current flowing from the left foreleg to the tail. The current readings were from 0.7 to 1.05 amperes. Seven of the animals were given artificial respiration. One that breathed spontaneously at first, stopped and could not be saved. One animal never breathed at all. Three rats (25 per cent.) died at once following the shock, four (33 per cent.) were paralyzed, and five (42 per cent.) survived the injury. The paralysis of the hind legs was due to burning and not to lesions in the spinal cord. These experiments again make clear the importance of watching that respiration does not cease, once it has become established. One rat breathed fast and irregularly for hours following the shock. The animals that survived could not be kept alive permanently owing to the extensive burns.

Discussion.—With the 1,000-volt continuous circuit there seemed to be little difference in mortality depending on whether the current flowed from right foreleg to tail or from left foreleg to tail. Forty-two per cent. survived in both instances. The results may now be summarized for alternating and continuous 1,000-volt circuits when the path of the current was from

either foreleg to the tail. With the alternating circuit 46 per cent. recovered from the initial shock, and with the continuous 42 per cent. These figures seem to correspond rather closely, but it must be remembered that the burns were so severe in the continuous series that the animals which recovered from the initial injury had no chance of permanent survival. The animals in the alternating group which survived the shock without paralysis had a good chance for complete recovery. The animals paralyzed with the alternating circuit never lived longer than three days.

The experiments reported thus far show that the continuous circuit produces fewer immediate deaths when the path of the current passes from the forelegs to the tail than when the current traverses the head. With the alternating circuit there are less significant differences. Previous studies have shown that the 1,000-volt continuous circuit produces more severe injuries in the nerve cells of the brain than does the 1,000-volt alternating circuit. The burns produced by the 1,000-volt continuous circuit are much more severe than those caused by the 1,000-volt alternating circuit. They lead to death within a few days in every case.

Electrodes Applied to Right Foreleg and Left Foreleg

Alternating Circuit.—In four rats, the pathway of current from a 1,000-volt alternating circuit was from the shoulder of one foreleg to the shoulder of the opposite foreleg. The current, from 0.7 to 1.17 amperes, flowed for two seconds. The heart beat for a considerable time following the injury. Artificial respiration was used in every case. Two of the four rats made attempts at breathing but in none of them could normal respiration be established, and they all died, making the mortality 100 per cent.

When an electric current passes through the body the greatest heat is produced at the electrodes, owing to the current concentration at these points. In the present group, where the electrodes were attached on the two sides of the chest, separated by only a short distance, the heating was extreme. There was an immediate coagulation of the protoplasm in the muscles of the forelegs and over the chest wall, and the whole chest was warm to the touch. It is remarkable that the heart continued to beat. It is not strange that none of these rats survived the injury.

Continuous Circuit.—Four rats were utilized in this series. The pathway of the 1,000-volt continuous circuit was from the shoulder of one foreleg to the opposite foreleg. The current ranged from 1.2 to 1.8 amperes. In three of the rats the heart beat following the shock; in the other no cardiac contraction could be detected. Artificial respiration was applied in every case, and two of the rats attempted to breathe but respirations never became established. The mortality was again 100 per cent. The heating and burning was even greater than in the alternating series just described. There is no possibility of survival in an experiment of this kind.

Electrodes Applied to Right Hind Leg and Left Hind Leg

Alternating Circuit.—The alternating 1,000-volt current was applied to

seven rats through electrodes attached to the two hind legs; the current of 0.62 to 1.2 amperes flowed for two seconds. All these rats breathed at once following the opening of the switch and no artificial respiration was required. One rat died ten minutes following the shock, from neglect. The others were not quiet nor did they show any evidence of shock. The hind legs were stiff in two, probably owing to burns near the site of the electrodes.

The results obtained in this series suggest that the inhibition of respiration is less marked the farther the pathway of the current is separated from the nervous system. The direct pathway of the current in these rats not only did not pass through the brain but also avoided cervical and thoracic portions of the spinal cord.

Continuous Circuit.—The 1,000-volt continuous circuit produced greater damage than did the alternating circuit when the pathway of the current was from one hind leg to the other. Seven rats were studied in this way; the current of 0.8 to 1.8 amperes flowed for two seconds. Five of the animals breathed at once; artificial respiration did not save the other two although they made some attempts to breathe. The burns were more severe than those caused by the alternating current, and none of the rats lived for more than three days following the experiment. The block of the respiratory mechanism in this case was very small, as evidenced by the number that breathed at once following the shock.

Electrodes Applied to Right Foreleg and Left Hind Leg

Alternating Circuit.—The current from a 1,000-volt alternating circuit was allowed to flow from the right foreleg to the left hind leg in the case of four animals. The current readings were from 1.06 to 1.14 amperes. Artificial respiration was used in each case; two of the rats died of the initial shock after unsuccessful attempts at breathing. The hind legs of one rat were paralyzed. The two survivors, including the paralyzed rat, were very active soon after the shock.

Continuous Circuit.—Four rats were injured with a continuous 1,000-volt circuit, the pathway of the current running from the right foreleg to the left hind leg. The currents were from 1.2 to 1.7 amperes. Artificial respiration was used in each case but none of the rats survived the initial shock. No heart beat could be detected in two after the circuit was opened. The heart beat strongly in the others, and one animal attempted to breathe but died almost at once. This circuit produced, therefore, uniform, fatal results.

Electrodes Applied to Left Foreleg and Left Hind Leg

Alternating Circuit.—The pathway of the current from the alternating 1,000-volt circuit was from left foreleg to left hind leg in four experiments. The currents were from 0.68 to 1.06 amperes. Artificial respiration was used in every case; two of the animals died without attempting to breathe. One attempted to breathe and then died; the other survived the injury well.

Continuous Circuit.—Four animals belong in this group in which the continuous 1,000-volt circuit was attached to electrodes on the left foreleg and the left hind leg. The current of 1.25 to 1.7 amperes flowed for two seconds.

No heart beat could be detected in one of the animals. Artificial respiration was used in the case of all; although three attempted to breathe, they died almost immediately.

Electrodes Applied to Left Foreleg and Right Hind Leg

Alternating Circuit.—Four animals were subjected to the 1,000-volt alternating circuit with the electrodes attached to the left foreleg and the right hind leg. Artificial respiration was used in every case. Two of the rats never breathed; the other two recovered.

Continuous Circuit.—Similarly four rats were shocked with the continuous circuit, the current flowing from the left foreleg to the right hind leg. All were given artificial respiration; two never breathed, another died after a few attempts at respiration, and the fourth survived for two and a half hours.

Discussion.—A summary may be given of the results of contact with either alternating or continuous circuit when the electrodes were applied to one foreleg and one hind leg. There were twelve rats in the continuous series and twelve in the alternating series. Artificial respiration was used in every case. The current readings in the two groups are nearly identical. No rats survived the contact with the continuous circuit. In the case of three of these rats it is believed that the heart was seriously injured so that it did not beat following the shock. In the alternating group 33 per cent. survived the initial shock, 8 per cent. survived but were paralyzed, and 59 per cent. died at once. The continuous circuit in this case was clearly more dangerous than the alternating.

The results in this series are closely analogous to those with the electrodes on the head and tail. The danger of the present circuit lies in the low resistance of the current path through the body, and this is believed to be the cause of the high mortality found. When one contact is made with the tail, the current is limited because of the resistance offered by the small cross section of this appendage. It is because of the high currents obtained with the contacts applied to the foreleg and the hind leg that the mortality in this group is almost as high as it was in cases where the current traversed the head.

Discussion

In a previous paper by the present authors (3), Urquhart's experiments published in 1927 (2) were given considerable attention. He believed that when an electric current passed through the brain, a temporary physiologic block was produced in the respiratory center so that spontaneous breathing was not normally initiated for some time. If no severe damage to the heart had occurred, it might be expected that adequate artificial respiration would give time for centers in the medulla to recover and normal breathing to begin. This theory seems correct and is supported by all our findings. It does seem probable, however, that the damage may be so great that the time required for recovery will be too long to permit life to be supported in the interval. Maclachlan (1) reports one case of human injury in which artificial respiration, continued for eight hours, finally permitted recovery.

Langworthy (4) (5) studied the injuries produced in the cells of the

nervous system by contact with electric circuits. At 1,000 volts, more serious injuries were produced with the continuous than with the alternating circuit. Many cells were damaged so severely by these high voltage shocks that it was felt that the cells could never recover. Moreover many large hemorrhages were found, particularly in the cord. The process of cell recovery was followed in the rats that survived the initial injury. In many cases the burning at the site of the head electrode produced necrosis of the skull and lesions of the underlying cortex.

More recently Urquhart (7) has confirmed his findings of temporary block in the respiratory center and has found that a similar block may be produced in the lower portion of the spinal cord of decerebrate cats and even in peripheral nerves by contact with alternating electric circuits.

TABLE 1.—CONTACT WITH 1,000-VOLT CIRCUIT FOR TWO SECONDS

POSITION OF ELECTRODES		CIRCUIT	NUMBER SHOCKED	PERCENTAGE REQUIRING ARTIFICIAL RESPIRATION	PERCENTAGE IMMEDIATE RECOVERY	PERCENTAGE PARALYZED	PERCENTAGE IMMEDIATE DEATH
Head	Tail	Alternating	16	88	31	38	31
		Continuous	3	100	0	0	100
Right foreleg	Tail	Alternating	12	58	33	25	42
		Continuous	12	50	42	33	25
Left foreleg	Tail	Alternating	12	75	58	17	25
		Continuous	12	58	42	33	25
Either foreleg	Tail	Alternating	24	67	46	21	33
		Continuous	24	54	42	33	25
Right foreleg	Left foreleg	Alternating	4	100	0	0	100
		Continuous	4	100	0	0	100
Right hind leg	Left hind leg	Alternating	7	0	86	0	14
		Continuous	7	29	71	0	29
Either foreleg	Either hind leg	Alternating	12	100	33	8	59
		Continuous	12	100	0	0	100

These findings have a particular bearing upon the present experiments. For it seems very probable that when the path of the current involves the chest, for example, a temporary block may be produced in the vagus nerves which causes a suspension of respiration. Block produced by the current

traversing the cervical portion of the spinal cord may bring about the same results. It is quite clear from the present work that a current flowing through only the caudal portion of the body is much less likely to produce a temporary suspension of respiration.

Microscopic study of the central nervous system of all the rats in the present series will be made. It will be extremely interesting to determine whether cell changes can be demonstrated in cases where the current does not pass directly through the brain. Undoubtedly heating may produce much damage when the current is allowed to flow for a considerable time.

The summary of the experiments given in Table 1 may now be discussed. The amount of the current averaged well in the whole series of experiments although the resistance was slightly higher with the continuous than with the alternating circuit. When one electrode was attached to the dorsal surface of the skull no rats survived the continuous circuit and 31 per cent. recovered from the alternating. This agrees with previous results obtained by the authors who found that the continuous circuit produced greater nerve cell destruction than the alternating circuit.

When the current flowed from either foreleg to the tail, 42 per cent. of the continuous group recovered from the immediate effects of the shock and 46 per cent. of the alternating. Moreover the rats injured with the continuous circuit suffered more severe burns. Artificial respiration was required in the case of many of the animals, suggesting a respiratory block, perhaps in the vagus nerves. The heart beat well following the shock in almost every case.

No animals shocked either from the continuous or from the alternating circuit survived a current flowing for two seconds between the two forelegs. Marked heating and burning occurred and in several cases no heart beat could be detected when the circuit was opened. When the current flowed between the two hind legs the injury was very much less severe. Under these conditions artificial respiration was required in none of the alternating circuit group and in only 29 per cent. of the continuous. One of the alternating series died; 71 per cent. of the continuous series survived the shock. Moreover these animals were bright and active as soon as the electrodes were removed.

Finally, it must be realized that respiratory block is not the only or perhaps the chief cause of death following electric accidents in man. In many cases, particularly after contact with circuits at low voltages, it is believed that ventricular fibrillation is induced which is responsible for the fatal outcome. In this connection it is important to mention the recent experiments of Hooker (8) (9) who has found that injections of potassium chloride solutions will stop the fibrillations and the heart will then beat again at normal rhythm.

Summary

This series of experiments record the damage produced in the respiratory mechanism by an electric current in cases where the pathway of the current does not pass directly through the brain. Rats were used as experimental animals inasmuch as the heart is resist-

ant to damage by electricity. In all the different leads, allowing the current to pass between the two forelegs or the two hind legs, or from foreleg to tail or hind leg, it was found that the continuous circuit produced more damage than the alternating. This was not always clear cut in a consideration of the number of animals that recovered from the immediate effect of the shock. It was found, however, that no rats subjected to the continuous circuit would survive permanently. This was largely due to the burning and destruction at the site of the electrodes which was greater in the case of the continuous circuit.

The deaths due to paralysis of respiration were not so frequent when the current did not pass directly through the brain but even so, many died from respiratory failure. When the current flowed between the two hind legs most of the animals breathed spontaneously and showed no evidence of shock. This suggests that respiratory block is less severe when the current does not pass directly through the chest or the upper portion of the spinal cord.

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J. I. H.
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PHYSICAL IMPAIRMENT AMONG ONE THOUSAND NEGRO FACTORY WORKERS*

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THOSE interested in the welfare of negroes have been impressed with their mortality rates, which for a long time have been much higher than for the white population, the greatest variance being in cities of northern states. The general mortality rate for negroes in Cincinnati has always been much higher than for whites and for a number of years tuberculosis, diseases of the circulatory system and of infancy, and syphilis have in the main contributed to this excess mortality.

All the conditions which play a part in bringing about these higher death rates are not yet clearly established, but recent studies, notably by Dublin (1), indicate that environment and lack of knowledge of personal hygiene are largely responsible. From what has been recorded on the history of the negro in this country, one is led to conclude that he thrives best in the South. Records are available to show that in the days of slavery, mortality rates in some southern cities were as low for these people as for whites. In this period, most of the negro population lived on southern plantations in an environment to which it could more readily adapt itself than to conditions in the North. It was at this time and under these conditions of rural life that the negroes thrived best in all their existence in this country.

After the Civil War the picture changed abruptly. The negro race, freed from the bonds of slavery, was left to its own resources for existence, and in this period of readjustment suffered an appalling loss of life from disease. The situation has improved, notably in the last two decades, but is not yet satisfactory.

Following the World War, with the advent of laws restricting immigration from Europe, large numbers of negroes left rural areas of the South to take up labor pursuits in the North. Cincinnati has been one of the main gateways to this northern migration, and being a large industrial center, has served as a place for increasing numbers to find employment. In the last ten years the negro population has increased from 7 to 11 per cent. of the total inhabitants of this city. Many of the males of this race group, now numbering more than 48,000, are industrially employed under conditions of hard, exacting, and often hazardous work. They have come to live in a colder climate, have low incomes, poor housing facilities, limitation of food and clothing, and usually cannot avail themselves of adequate medical attention.

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These conditions, together with their lack of knowledge of personal hygiene, contribute, we believe, in no small part to the high rate of mortality among the colored people in this city.

Cincinnati welfare agencies, both official and voluntary, have been greatly concerned with the health problem of the negro, and have spent much time in an endeavor to improve the situation; this is reflected in part by the downward trend in general mortality rate among these people in recent years. The city maintains a hospital where colored people may have medical attention and care; the Department of Health and voluntary health agencies provide free clinical service; and visiting nursing service and health education are extended to large numbers. Collectively these agencies have a fund of information concerning sickness among Cincinnati negroes but they have little information about those apparently well.

The value of the physical examination of apparently healthy persons as a means of disclosing the precursors of sickness, disability, and even death has been well demonstrated. Believing that an investigation of this nature would be helpful to those interested in the health of the negro, the Public Health Federation, a voluntary health agency in the Community Chest, and two of its associated agencies, the Anti-Tuberculosis League and the Heart Council, joined in a study of the health of 1,000 negro men employed in factory groups. As an initial step in this study, the group was carefully examined and the findings were tabulated and analyzed. The men will be followed up over a period of years, in so far as possible, in order to have their defects remedied and to determine the changes in their physical condition. The Anti-Tuberculosis League is now having X-ray examinations made of the chests of a large number of the group, and the results of these examinations are contemplated as the basis for a future report.

The Heart Council has for the past two years been conducting investigations on the extent of physical impairment among industrial workers, with particular reference to the circulatory system. The participation of the Heart Council in the present study had to do with supervising the physical examinations and gathering the data upon which this report is based. This negro group has, in fact, constituted a third in the Heart Council series of investigations (2).

General Considerations

This report is based on data derived from 1,032 physical examinations of negro industrial workers in the Cincinnati metropolitan area. Thirteen factory groups were represented in this survey, with the following distribution of workers:

Foundry (iron, brass, and aluminium)	423
Roofing manufacture	202
Cotton mattress manufacture	136
Chemical fertilizer manufacture	115
Leather tanning	92
Glass bottle manufacture	64

All the men examined were volunteers, drawn from the rank and file of those employed in these several industries; the only requirement was that they be 20 years of age or over. Generally speaking, their work may be considered as requiring little mental effort and moderately hard to hard manual

labor. Fifty-eight per cent. were rated as machine or hand tool operators, and 42 per cent. as ordinary laborers. This group does not include all types of industry in the metropolitan area where negroes are employed. On the other hand, we consider that it represents a fair cross section of those employed in the several manufacturing processes above specified.

The majority of the industrially employed negroes in Cincinnati come from the South; the actual percentage is not known. In this group of 1,000 factory workers, however, almost 90 per cent. gave some southern state as their birthplace, while only 1.7 per cent. were born in Cincinnati. It is evident from our records that out of the increasing thousands of young negro men making their way northward through this city, many go no farther because here they find employment and other conditions satisfactory for residence.

We pointed out in our second report, dealing with 1,000 white machine and hand tool operators, that a majority of the group (77.2 per cent.) were under 45 years of age. In view of our interest in the extent of circulatory impairment at middle age and beyond, we tried to include men of ages that would be comparable to those in the clerical group, where the majority fell between 30 and 55 years of age. We failed for the reason that older men are not found in large numbers in factory groups. Again in the negro study we found a dearth of older man employed; here even a greater majority (79.8 per cent.) were under 45 years of age. Our experience in these studies reflects in a small way the tendency of industry toward the elimination of older men.

Medical History

Preliminary to the physical examination, every man was carefully queried by an experienced worker concerning his medical history. We shall mention but a few items in this connection which are considered to be of some significance.

As might be expected, the acute infectious diseases led as causes of past illnesses. Among the chronic infectious diseases, gonorrhea was found to head the list, followed by syphilis and tuberculosis. The last-named disease was recorded in but eight instances. In 3.2 per cent. of cases there was no history of past illnesses.

Six hundred and twenty-eight gave no history of surgical operations. Among the others, accidents were the most common cause for surgical care. Thirty had had tonsillectomy, and seventeen appendectomy.

It is significant that 421 men were found by query and inspection never to have been successfully vaccinated against smallpox. In fact, out of the 1,000, only 139 had been vaccinated within five years. It is therefore obvious that many local employers do not make smallpox vaccination a requirement for employment.

One other interesting item in the medical history has to do with dental care. Here we found that 266 out of the group had never visited a dentist, and 627 had dental care only upon emergencies. Six men said that they visited the dentist twice a year.

Physical Findings

The examining group was made up of one white and one negro physician. The former conducted the examina-

tions of the cardiovascular system and lungs, while the latter carried out all other parts of the examination. No set period of time was prescribed, the examiners being allotted as long a period as individual cases warranted to secure the best possible estimate of the examinee's physical status. In instances where findings appeared to be indefinite or where there was some doubt in the mind of the examiners, expert counsel was obtained or examinations were repeated.

It may well be surmised that our interest in this study centered about cardiovascular findings. While we were particularly concerned as to the extent to which cardiovascular abnormalities would be found, we did not place undue emphasis upon the examination of these organs at the expense of slighting other items. We were quite mindful that should this be done, our attempt later at correlating the cardiovascular findings with others would prove of little avail. Again, it is not maintained that the examinations were exhaustive; for instance, routine neurologic and psychiatric testings were not attempted. Our examining group was limited and we did not deem it feasible to keep men from their work for an undue length of time. We do believe, however, that this survey has enabled us to arrive at a fair estimate of the physical status of this group of negro factory workers.

As an initial step in the examination procedures, every subject was carefully inspected for any abnormal condition which could be readily observed, such as gross disproportion of weight, defects of posture, skin lesions, and deformities. Seventy-two per cent. of the group were rated as presenting some abnormal condition observed upon this preliminary inspection.

Weight.—Examinees were routinely measured for height and weight, both measurements being made with all clothing removed. Weight status was determined in accordance with life insurance (Union Central) standards, with the result that 367 fell in a class within 10 pounds of best standard weight, 358 in a class 10 pounds or more above, and 275, 10 pounds or more below the respective standard deviations allowed for height and age. Those overweight to the extent specified were distributed almost equally above and below 40 years (49.5 per cent. and 50.5 per cent., respectively). On the other hand, of those underweight, 74 per cent. were under 40.

Eyes and Vision.—It cannot be maintained that the negro industrial worker is much concerned about his vision so long as he can readily find his way about in the course of his daily tasks. Some wear glasses for the sake of appearance, but not to aid vision. Little wonder, then, that visual defects were commonly met in this class of workers. Some eye defect was noted in 638 men. Over half of the entire group (508) were found to have a deviation of 20/30 or more in one or both eyes, and nine out of every ten had made no effort at correction.

Visual defects were found to be more common with advance in age, but effort toward correction was not manifested to any appreciable extent in any age group, and complete correction was noted in only seven cases.

A conspicuous number were recorded to have defective color perception. This we have attributed largely to color ignorance, and we were at a loss

to know how much color blindness actually existed.

Teeth.—The history of dental care will bear repeating since this information gives a proper setting to our account of dental defects. In this group of 1,000 men, 266 have never visited a dentist; 627 stated that they had dental care only in emergency; and six indicated that they visited a dentist twice a year. Referring now to our records of dental examinations, we find that there were 787 in need of dental care, of whom 62 per cent. had infected gums, 47 per cent. had carious teeth, and 43 per cent. had five or more teeth missing. A little more than one-fourth of all the men (26.2 per cent.) possessed heavy dentistry. Crowns were commonly found, and it was learned that in many instances they are placed over sound teeth as a means of adornment.

Hearing.—Because of the interference of factory noise, which could not be entirely overcome in most examining quarters, the data concerning our estimate of diminished hearing are probably not very accurate. By means of the whisper test, examiners considered 107 men to have impairment of hearing in which impacted cerumen was a cause of note.

Upper Respiratory Tract.—Evidence of sinus disease by history and examination was found in one-fourth of the group and constituted the most common defect of the upper respiratory tract. Of throat abnormalities, enlarged tonsils were most frequently observed, and infected tonsils were by no means uncommon. Twenty men had had tonsillectomy.

It would seem from these findings and those before mentioned that store glasses or gold crowns for the sake of outward show have often been preferred to having conditions remedied for the sake of internal benefit. This circumstance reflects the further need for health education.

Chest and Lungs.—In the introductory remarks of this report, the Anti-Tuberculosis League was named as one of the three agencies participating in this investigation. As one of its projects this organization is having X-ray examinations made of the chests of a large number of the group, for evidence of tuberculosis. Diagnosis of pulmonary tuberculosis by means other than the X-ray is known to be difficult, and a decision usually requires repeated examination. The results of one rather brief physical examination per individual, such as was carried out in this survey, must be accepted as a crude estimate of actual pulmonary pathology. In all fairness to the examining physician, who conducted these examinations in a painstaking manner, we have chosen to withhold, until such time as X-ray evidence has been secured, some of the details pertaining to the pulmonary findings.

It may be stated that manual examination did not reveal any active tuberculosis, but thirty-nine men were suspected of being tuberculous. In all, 145 of the group possessed abnormalities of the chest or lungs.

Heart and Vascular System.—In this group of negro factory workers, we reached a new peak in our investigative experience in the incidence of cardiovascular impairment. Significant cardiovascular abnormalities were found in 55.6 per cent., with a striking number under 40 years of age. Not only do these findings stand out as of

significance in many respects, but they also indicate in some measure an explanation of the notably higher mortality rates from heart disease in this race. The findings relative to cardiovascular impairment have been set aside for further consideration in a separate report.

Abdomen.—Of the 193 abdominal defects, 147 were hernias, many of which were umbilical. Among other conditions of note was tenderness, which in most instances was not traced to the probable source of trouble. A few men were found to have enlarged livers. Generally considered, the abdominal examinations revealed less than might be anticipated from this class of industrial workers.

Skin.—Traumatic scars dominated the picture in skin defects, but they were much more frequently the result of a wildly wielded razor than of the surgeon's knife. Acne was common, industrial dermatoses were uncommon, and fungus infections were not observed.

Extremities.—In this connection flatfoot comes first to mind and rightfully so, for it eclipsed in number of cases all other types of defects found. There were 816 men with flatfoot, and the condition was marked in 243 instances. The nature of the work would, of course, preclude many with other defects of the extremities.

Genito-Urinary.—Two hundred and thirty abnormal conditions were recorded for the genital organs, which, in view of the medical history, is not surprising. Penile scars and atrophied testes were among the more common observations.

In the urinary findings, albuminuria was conspicuously high. Seventeen per cent. of urine samples showed a definitely positive test for albumin. There were but four instances of glycosuria.

Glandular.—As a part of the examination procedure, lymph nodes in cervical, axillary, inguinal, and other accessible regions were palpated for unusual enlargement, and evidence of any dysfunction of the thyroid or other endocrine glands was noted. General adenopathy of the lymph glands was a common experience. Enlarged inguinal nodes led in frequency and a large number of men were found to have palpable epitrochlear nodes.

The only records concerning endocrine dysfunction had to do with the thyroid. Simple enlargement was noted in thirty-nine men and seventeen others were suspected of having hyperthyroidism.

Summary and Conclusions

Those of us who have closely followed this investigation marvel that these men can carry on day after day at tasks exacting moderate to great amounts of physical effort. As a matter of fact, we know that many of them break down relatively early in life, as a result of serious physical defects. Tuberculosis, syphilis, and the degenerative diseases are still exacting a large toll of life among these people, so great in fact that comparatively few survive to reach old age.

In this study we have arrived at what is considered to be a fair estimate of the physical status of 1,000 negro men, most of whom are in the earlier age groups—a small sample of this population in Cincinnati, to be sure, yet it serves as a basis for predicting that a very large amount of physical

impairment probably exists in this race group at large. Some conception of the situation may be gained from a summary of all the findings:

Out of this group of 1,000 negro factory workers, only one was found who was considered to be essentially free of defects. As to the rest, 88 had minor defects only; 911 had significant physical defects; 556 had significant cardiovascular defects; 996 possessed defects, either minor or significant, which were unknown to them—at least they did not state that they knew of them; 977 would, in the estimate of examiners, profit by early medical care.

We wish to make due acknowledgment of the valuable services rendered by Miss Katherine Hoenig in the conduct of this study and in the compilation of the data upon which this report has been based.

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   I. Physical Impairment among 1000 White Male Clerical Workers.
   II. Physical Impairment among 1000 White Male Machine and Hand Tool Operators.
   III. Physical Impairment among 1000 Negro Male Factory Workers.

CARDIOVASCULAR IMPAIRMENT AMONG ONE THOUSAND NEGRO FACTORY WORKERS*

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IN our report on physical impairment among negro factory workers, we made brief mention of cardiovascular impairment. The data with reference to these findings and certain correlations were considered of sufficient importance to be discussed apart from the general report. We shall, therefore, present in these pages the cardiovascular findings derived from the physical examination of 1,000 negro factory workers employed in the Cincinnati metropolitan area.

All testings of the cardiovascular system were rated as normal or abnormal through the use of the same carefully selected standards which have been applied to all studies thus far made in this series.[1] Cardiovascular lesions were rated as significant or minor. In the former class were included all hypertension, hypotension, definite cardiac hypertrophy, valvular lesions, myocardial insufficiency, and marked arteriosclerosis. Minor lesions constituted slight or unproven hypertrophy, slight to moderate arteriosclerosis, arrhythmias, tachycardia, and bradycardia. We shall consider in this report only the significant lesions.

Among the white machine and hand tool operators in our second group, we found 31 per cent. with significant cardiovascular abnormalities, and in the clerks in the first group, 36.1 per cent. The negro factory workers in the present group, however, showed 55.6 per cent. with significant lesions—a strikingly higher incidence than for the white workers.

Among the negro men with cardiovascular lesions it was found that 249 had cardiac enlargement; 125 had valvular lesions; 68, myocardial insufficiency; 368, abnormal blood pressures —249 hypertension and 119 hypotension; and 11, marked arteriosclerosis.

ANALYSIS OF DATA

Cardiovascular Lesions and Medical History.—In analyzing the data, many items recorded in the medical history were correlated with circulatory findings in order to determine whether any relation existed. A few notations have been selected for brief mention.

Upon correlating the history of past

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[1] The Heart Council of Greater Cincinnati, Life Conservation Studies: I. Physical Impairment among 1000 White Male Clerical Workers. II. Physical Impairment among 1000 White Male Machine and Hand Tool Operators. III. Physical Impairment among 1000 Negro Male Factory Workers.

illnesses with cardiovascular findings, it was found that the rates for articular rheumatism, typhoid fever, and measles were appreciably higher for the men with cardiovascular abnormalities than for those without such abnormalities. The rates for tonsillitis and influenza were lower for those with cardiovascular lesions; the rate for syphilis was precisely the same for both groups.

In the list of present complaints it was observed that higher rates for dysuria, fatigue, loss of appetite, and epistaxis obtained for the cardiovascular group. Headaches, colds, nocturia, cramps, dyspnea, and palpitation were much more common as complaints among men with abnormal blood pressure.

Weight and Cardiovascular Lesions.—In all groups thus far examined there has been a greater incidence of cardiovascular impairment among men who were overweight. In this group of negro factory workers, 367 were within 10 pounds of normal weight, 358 were 10 pounds or more overweight, and 275, 10 pounds or more underweight. Cardiovascular lesions were least commonly associated with weight 20 pounds or more below normal, and most commonly met where weight was in like amounts above normal. The percentage relations are shown in Table 1.

Among those under 40 years of age, 27.4 per cent. were overweight; among those over 40 years, 52 per cent. It is interesting to note the correlations between overweight and cardiovascular defects in the two groups at this age division as shown in Table 2. A definitely higher incidence of cardiovascular impairment obtains for men over 40 regardless of their weight status, and there is little fluctuation in the rates. Below 40 years the situation is quite different in that the greater the amount of overweight, the higher is the incidence of cardiovascular findings. Are these trends influenced by chance groupings or is overweight among young negro men a factor to be associated with a greater prevalence of cardiovascular disease? Although these differences appear of significance, we are not at this time in a position to draw any definite conclusions.

TABLE 1.—WEIGHT AND CARDIOVASCULAR ABNORMALITIES IN 1,000 NEGRO MALE FACTORY WORKERS

WEIGHT STATUS	CARDIOVASCULAR LESIONS
	%
20 lbs. or more underweight..	37.0
10–19 lbs. underweight.....	43.7
Within 10 lbs. of normal weight.....	52.4
Whole group.....	55.6
10–19 lbs. overweight.....	64.6
20 lbs. or more overweight....	74.5

TABLE 2.—OVERWEIGHT AND CARDIOVASCULAR ABNORMALITIES IN 1,000 NEGRO MALE FACTORY WORKERS

	UNDER 40	OVER 40
	%	%
General rate for cardiovascular lesions.....	46.0	74.0
Within 10 lbs. of normal weight.....	43.5	78.5
10–19 lbs. overweight...	50.5	81.0
20 lbs. or more overweight.....	70.9	77.9

Blood Pressure.—The findings with reference to blood pressure in this group of men are very interesting. Of the 1,000 negroes, 632 fell within insurance (mean) standards, and 249 were above, and 119 below these standards. The total with elevated blood pressure commanded our attention because of the unusually high number involved and because of the age group distribution. The curve for incidence of hypertension in this group by age is higher for men over 30 years than the curves based on insurance statistics and on findings in other surveys similar to this, which have come to our attention. In this connection it is of some significance, we believe, that 17.7 per cent. of all the men under 40 years had hypertension; this includes 13.8 per cent. of those up to 30 years and 21.5 per cent. of those between 30 and 40.

In view of this unusual picture we determined to make second readings on a fair sample of examinees who were previously found to have high blood pressure. Accordingly, 120 of these men selected at random were tested several weeks after the initial examination. The first and second readings were then correlated in order to determine the probable error. It was found from this procedure that the index of correlations between the first and the second readings equaled 0.717 ± 0.03 as the probable error. With due allowance for probable error to the extent indicated, the findings are still notably higher than those obtained in other studies. Further discussion will be given to hypertension where other data have been correlated.

The findings with reference to low blood pressure are quite in accordance with our previous experience as well as that of others. Of all examinees with hypotension, 48.7 per cent. were under 40 years; 26 per cent.—the highest percentage in any one age group—were between 40 and 45 years.

Weight and Blood Pressure.—The tendency for elevated blood pressure in overweight persons is a common observation. We noted a consistently higher occurrence of hypertension among overweights in Studies I and II, and Table 3 reveals the same situation to have existed in the group under consideration.

TABLE 3.—WEIGHT AND ABNORMAL BLOOD PRESSURES IN 1,000 NEGRO MALE FACTORY WORKERS

WEIGHT STATUS	HYPER-TENSION	HYPO-TENSION
	%	%
20 lbs. or more underweight	14.8	11.8
10–19 lbs. underweight.	17.5	11.4
Within 10 lbs. of normal weight	22.0	14.2
Whole group	24.9	11.9
10–19 lbs. overweight	27.8	13.9
20 lbs. or more overweight	39.5	7.0

The rates determined for hypertension in relation to weight show a steady rise, from 14.8 per cent. for those 20 pounds or more underweight to 39.5 per cent. for those 20 pounds or more overweight. Hypotension, on the other hand, shows an irregular variation with weight; it is least common to those most overweight and most common to those of normal weight.

Wassermann Findings and Cardiovascular Lesions.—Blood Wassermanns were obtained from 362 members of the group. Out of 183 of this number

who had cardiovascular lesions, fifty-two, or 28.4 per cent., showed 3 plus or 4 plus Wassermanns. Of those with positive reactions, 22.8 per cent. had hypertension, as against 18.2 per cent. of those with negative reactions.

Urine Findings and Cardiovascular Lesions.—Specimens of urine from 991 examinees showed 170 to have albuminuria and four, glycosuria. The incidence of albuminuria in men with cardiovascular lesions was 20 per cent., as compared with 13.4 per cent. in men without such lesions. Glycosuria was noted in 0.5 per cent. and 0.2 per cent., respectively.

General Comment

In our Studies I and II we found that 33.5 per cent. of the two groups had significant circulatory defects; in the negro group, 55.6 per cent. were involved. This means that the colored rate was 1.6 times the white. The difference in ratio here noted, 1.6:1, closely approximates the general mortality experience for Cincinnati, which for the ten-year period ending 1929, averages 1.7 (negro): 1 (white). Higher mortality rates among negroes from circulatory causes have been observed elsewhere. Dublin (1), Wood, Jones, and Kimbrough (2), and others have reported negro rates amounting in some localities to as much as twice the rate for the white population.

It should be borne in mind, however, that a preponderance of the men included in this study were under 40 years of age. For this reason we have on several occasions considered the findings derived from examinees below and above this age level; we believe that in any study of impairment, emphasis should be placed on age distribution.

We have been impressed with the fact that nearly half of all cardiovascular impairment which was found to exist in this group occurred among the men under 40 years of age. The percentage of hypertension is conspicuously high for all age groups over 30. Wood and his coworkers (2) hold that hypertensive and syphilitic heart disease are in the main responsible for the higher incidence of circulatory impairment among negroes. Our findings tend in part to bear out these observations. Hypertension constituted 45 per cent. of all cardiovascular findings; hypertension and cardiac hypertrophy combined, accounted for 90 per cent. The contention made by Thom (3) that syphilis is frequently associated with elevated blood pressure is also borne out in our findings, but the evidence is not striking.

The association of overweight with a greater incidence of cardiovascular impairment is as evident in this group as it has been in previous groups investigated here and elsewhere. In the negro group, members under 40 years of age show the more definite trend, whereas those over 40 display little influence of the factor of overweight.

The cardiovascular-renal syndrome is probably reflected in the correlation of cardiovascular with urinary findings, where albuminuria was observed to be conspicuously more common among men with circulatory impairment.

Summary

In a group of 1,000 negro male factory workers employed in the Cincinnati metropolitan area, 55.6 per cent. were found to have significant cardio-

vascular abnormalities. This rate is notably higher than that of 33.5 per cent. found among 2,000 white male workers in this locality. This difference in rates closely approximates the local mortality experience over a period of years.

A striking number of men under 40 years were found to have significant cardiovascular lesions. Hypertension and myocardial hypertrophy predominated in these findings.

Rates for cardiovascular lesions were definitely higher among those overweight and with albuminuria or glycosuria. Men overweight or with positive Wassermann reactions were more prone to hypertension.

Conclusions

We do not regard the number examined in our series as yet sufficient to permit drawing any definite deductions. The Heart Council contemplates further studies along these lines and a follow-up of those examined over a period of years. A comparative study of the three groups thus far incorporated in our series will, we believe, unfold some information of value.

A high percentage of these negro workers were unaware of any unsound condition of their circulatory system as well as of other major defects possessed by them. One conclusion is therefore obvious: the evidence cited here and in our previous report reveals the need for wider use of the periodic health examination.

We wish to make due acknowledgment of the valuable services rendered by Miss Katherine Hoenig in the conduct of this study and in the compilation of the data upon which this report has been based.

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J. I. H.
May, 1931

THE INTERNATIONAL SILICOSIS CONFERENCE HELD AT JOHANNESBURG, AUGUST, 1930*

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THE published proceedings of the International Silicosis Conference will reveal our knowledge of one of the chief industrial diseases as well as our ignorance of many things relating to its causation and prevention. These proceedings will probably remain for many years the standard volumes of reference on silicosis and other dust diseases of the lungs. However, these evidences of things done, these careful records of facts, opinions, and experiences, will not constitute the chief blessings from the Conference.

The great stimulus for further work which all received from personal contact with international colleagues must make work of research in causation and prevention prosper. From many countries those interested in the prevention of dust diseases of the lungs have come into personal touch, and there has been created a nexus from this meeting which promises a widespread application of approved methods for the study and prevention of these diseases.

PREVENTION

Dr. Middleton of Great Britain brought forward a well-considered scheme for the ordering of the discussions of silicosis under the headings Etiology, Diagnosis, Prognosis, and Prevention, and this program was circulated. He spoke on etiology and considered three factors: (1) exposure to dusts of free silica and combined silica; (2) the duration of exposure; (3) the intermittency of exposure.

He stressed the need to determine the standard of air dustiness which produces silicosis, and mentioned the figure laid down on the Rand and in Sydney; he spoke of the fact that exposures as short as two years cause silicosis, and of the preventive bearing of intermittency of employment in dusty occupations; he mentioned the influence of dust other than free silica, such as asbestos, and asked whether silica is deposited in a healthy lung or only in an affected lung. He thus raised many points not included in the published program; other speakers also broadened the subject for discussion, but Professor Loriga (Italy) pointed out that our attention should be centered on: first, the determination of the standard amount of dust tolerable to a person of average health; secondly, the means of reducing dust to this amount; and thirdly, the best methods of estimating dust in the atmosphere.

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An Australian delegate stressed the need for the study of a size-frequency ratio of particles, stating that at about 400 particles per cubic centimeter (using Owens' dust counter) dust particles below 10 microns with a size-frequency ratio of 3 do not form a visible cloud of dust. He noted the failure of the South African authorities to correlate particulate counts with gravimetric estimations. He expressed pity for those who still worked with the original Kotzé konimeter, but praised the recent work in the Chamber of Mines laboratory and the newer methods of the past year. When using the circular konimeter, Chance's heat resisting glass slides, and washing methods, counts were obtained that *prima facie* agreed with those got by other methods. He expressed the hope that further attempts would be made in South Africa to correlate konimeter counts with sugar tube results. In his opinion, Owens' dust counter is capable of doing all the work now being done on the Rand with the Kotzé and the circular konimeters, and it produces a record from which carbon particles and water soluble salts can be eliminated by selective counting.

It appeared that the average dust exposure on the Rand was about 1 mg. per cubic meter, or 110 particles per cubic centimeter of a size-frequency ratio of 3; if this is so, then the prospects of our attack on the disease by reducing the amount of dust inhaled seem rather hopeless.

Dr. Pirow (South Africa) did not agree with these views on the size-frequency ratio of dust particles and thought that Owens' dust counter required too much care for routine work. He said that attempts were being made to standardize konimeter practice.

Dr. Mavrogordato (South Africa) stressed the importance of size-frequency and mentioned the type of semi-dark ground illumination used in South African konimeter work. He gave his experience with Owens' counter and urged the adoption of a uniform method of dust estimation. Professor Hall (Great Britain) supported this idea, while Dr. Orenstein (South Africa) thought that two different methods of dust sampling were required, one for routine use and another for critical and scientific study, for which an international standard could be laid down.

Nothing of importance emerged from the discussion on dust masks, but Dr. Fisher (Great Britain) stressed the practical success of the Hay dust trap in drilling in coal mines; the konimeter counts taken are, however, very few. Useful working ideas were put forward that the area of intake in a mask should be made large to compensate for lack of permeability, and Dr. Bulmer's recent device was commended.

Dr. Mavrogordato dealt with the more recent views held by many Rand authorities that humid conditions underground aid the development of infectious conditions. As most of the silicosis now arising is of the so-called infective type, their minds are at present directed to methods of freeing the mine air of silica dust by ventilation rather than by the use of water to remove dust of micronic size. The dust which is inimical is invisible in concentrations which will produce silicosis, and the recent idea that we would better appreciate the problem if

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we regarded this dust as a gas has gained ground. The chief use of humid conditions, as outlined by several speakers, is to prevent the formation of fine dust and not for the removal of such dust when formed.

Dr. Middleton gave a clear exposition of the principles that should govern the application of exhaust ventilation to dusty processes.

Professor Koelsch (Germany) drew attention to the fact that in Solingen investigation has shown that cases of silicosis occur among wet grinders with considerably greater incidence and of a more severe type than among dry grinders. This fact is, in his opinion, related to the damp atmosphere. Dr. Russell said that there was a high incidence of silicosis and tuberculosis in the wet grinding industry in an American state but that it had been reduced by the substitution of dry grinding with an exhaust system.

Dr. Orenstein, reviewing the probable increase in virulence of Rand silicosis, asked whether water or something else was responsible for this. Later he demonstrated in cinema films taken underground how dust, invisible to the naked eye, was revealed by the film.

The possibility of preventing silicosis by admixture of adulterate innocuous dusts with silica dust was discussed. No clear instances of advantage could be cited by delegates and the general sense of the Conference seemed skeptical of any advantageous results being likely from this procedure. The use of hygroscopic methods for removing dust from the atmosphere was touched upon, and various substances were mentioned. Those tried out on the Rand were said not to have shown any advantage over water; moreover, they lose their efficacy in humid and wet mines.

Mr. Phelan, from his training as a physicist, suggested application of such a method as that devised by J. J. Thompson for counting ions in ionized gas. Certainly the subject of dust determination is one in which we require new ideas from physicists.

Dr. Orenstein pointed out the newer work of dust determination in photographic film manufacture, particularly the use of the photo-electric cell.

The reporters on the Section of Preventive Measures were Professor Loriga (Italy), Mr. Roberts (South Africa), and Dr. Badham (Australia). Extracts from two important paragraphs of their report, Nos. 3 and 4, read as follows:

> 3. From the information supplied by various members, the disease becomes noticeable after widely differing periods of exposure to siliceous dust, depending apparently upon:
>
> (*a*) The amount of dust inhaled;
>
> (*b*) The percentage of free silica contained therein;
>
> (*c*) The size-frequency (or fineness) of the particles inhaled;
>
> (*d*) The nature and sort of such other substances (including vapours and gases) as may be inhaled simultaneously, or otherwise;
>
> (*e*) The powers of resistance of the individual concerned;
>
> (*f*) The presence or absence of a complication by an infective process.
>
> It was agreed that by the use of water and other preventive measures the dust contents of air can fairly readily be reduced to ordinarily invisible amounts. In Australian experience this represents something in the neighbourhood of 4 or 5 milligrams per cubic metre, or say 400 or 500 particles per cubic centimetre when the particles are from 1 to 10 microns with a size-frequency

ratio of 3. It was, however, evident from the discussion that it is impossible, under existing conditions, properly to correlate dust determinations made in different countries, in different industries and for different purposes, as well as for different immediate objects.

The experience on the subject of certain members went to show that while exposure to various other dusts *simultaneously* with silica might affect the development of silicosis, the suggestion that other dusts might be used as an antidote against silica should be treated with great caution and reserve. Further research in this direction is urgently called for. It was pointed out that experimental evidence and practical experience under working conditions had shown that prior or subsequent inhalation of other dusts in no way delayed the development of silicosis.

In the course of the discussion under this heading some reference was made to the alleged immunity from silicosis in some districts where quartz in company with non-siliceous rock is mined, but it was pointed out that further investigation had shown in the one case that the allegation was unfounded, in that the existence of silicosis had been obscured by the migratory nature of the working population; while in other cases it appeared that by reason, possibly, of the absence of laws relating to compensation, the medical evidence is not so complete as it might otherwise be, and there is sufficient room for doubt as to the exact position of the workers vis-à-vis silicosis. In all cases where there are laws relating to the compensation of silicotics it is but natural that the examination of the workers will be more thorough.

There was a certain consensus of opinion that alternative employment and periods free from exposure to siliceous dust tended to increase the resistance and thereby delay the development of silicosis.

4. The discussion on methods for the prevention of dust and the inhalation thereof fell, on broad lines, under the following headings:

(*a*) The use of water;

(*b*) Exhaust draught applied at or near the point of origin of the dust;

(*c*) Dust traps and masks;

(*d*) Ventilation;

(*e*) Other methods.

There was something said in favour of each of the methods referred to. It was agreed that no one method is applicable in all circumstances, but that in most cases, and especially in mining, there should be a combination of methods.

With regard to water, it was pointed out that as far as the Witwatersrand was concerned, it is used in three different ways, namely:

(1) To prevent the formation of dust during the drilling of holes, in blasting, a nd the handling of broken rock;

(2) For the wetting of all surfaces with a view to securing a "fly-paper" effect in retaining dust which might settle on those surfaces;

(3) For spraying into the air in order to allay dust which had been formed.

In regard to (1) it was generally agreed that the application of water at the site of percussion or fracture tends to minimise the formation of dust, but attention was drawn to the fact that in several operations, *e.g.*, rock drilling, stone cutting, grinding, etc., sparks accompanied by dust escape even when the surfaces concerned are actually under a film of water.

In regard to (2), the view was expressed that since there is no particular reason why dust particles of the order of less than 3 microns should settle on the roof and sides of working places, and since they would settle on the floor only after many hours, the value of these wetted surfaces as dust catchers is probably small.

With regard to (3), it was pointed out that the dust particles with which the Conference was concerned are of the same order in size as micro-organisms, and that no one nowadays would expect to catch micro-organisms by means of a spray. In this connection it was mentioned as a matter of interest that Lord Lister, in his famous address delivered at Berlin, had stated that he felt ashamed of ever having suggested such a possibility in surgery.

The consensus of opinion was that as sprays are of little value for removing fine dust from the air and that since, further, a humid atmosphere and the presence of droplets had been shown experimentally

to increase the risk of various infections, their use should be restricted.

This view, however, does not necessarily apply to water blasts used on the Witwatersrand when firing in development ends, since while such blasts might not catch much of the finer dust (except by the subsequent condensation of water vapourised by the heat generated in blasting) they put into solution some of the noxious gases and wet the broken rock so as to prevent the escape of the dust when that rock comes to be handled.

In regard to (*b*), it was mentioned that exhaust draught was of great value in those processes of manufacture where there is an objection to the use of water. In some cases water cannot be used for fear of spoiling the material, and in other cases the workmen at times turn it off because it makes them wet. In all such cases, exhaust hoods should, if applicable, be used. It is necessary, however, that these hoods should be placed in close proximity to the work and that regard should be had to the direction and speed of rotating objects. As an example of what could be done in manufacturing processes by the use of exhaust draught, cases were mentioned of a decrease in the incidence of silicosis which had followed the abandonment of wet grinding in favour of dry grinding with suitably applied exhaust draught. It was also pointed out that before exhaust draught was used for the dry grinding of metals this process was much more dangerous than wet grinding, but that since the introduction of efficient exhaust draught with dry grinding the position has been reversed.

(*c*) *Dust Traps.* As an example of the application of this method to the drilling of holes in mines, mention was made of an apparatus wherein the drill steel operates through an artificial collar held against the face of the rock and through which ejector induced suction led the dust produced in drilling into a dust trap or filter. This apparatus was said to be very effective and popular in certain collieries to which laws relating to silicosis have recently been applied.

Masks. It appeared from the experience of members that workmen submit readily to their use only when discomfort from the inhalation of noxious dust can thereby be avoided.

In some circumstances loose-fitting masks of the pressure type wherein a constant supply of fresh air under positive pressure is led in through a flexible tube have proved very efficacious. Such masks, however, are useful only when the wearers can perform their work without the necessity of moving from place to place. The same applies to tight-fitting masks supplied with air at normal pressure through a tube from a distant source.

Other masks wherein air was inspired through a filtering medium such as cotton wool, sponges, etc., and expired through a light non-return valve, were also described.

Reference was also made to masks in which the air to be inspired is made to pass through a tortuous path and impinge on damp surfaces which will retain the dust.

The feeling of the Conference was that while the masks at present available may be of some value in special circumstances, and particularly in those cases where the formation of dust (and the consequent necessity for precautions) is intermittent; they are so unwieldy or interfere so much with respiration that their constant use is impracticable during hard work and especially in a hot and humid atmosphere.

In regard to (*d*)—Ventilation—there was but little direct discussion, it being agreed that good fresh air ventilation was desirable, and indeed essential. It was emphasised, however, that to be effective the ventilation currents must be properly split and directed so as to sweep all dust-laden air out of the mine or works, as the case may be, in much the same way as dangerous gases are swept out of collieries.

Their recommendations which were adopted by the Conference are:

1. While the methods of conducting and the details relating to the routine sampling of air can best be left to each local authority, it seems highly desirable that for certain special critical and scientific studies of dust particles in air and their effect, there should be established some standard method which for this special purpose would permit of inter-industrial and inter-national com-

parisons; in this connection it is suggested that the instruments at present approved by the various experts should be taken into consideration. The results of these investigations should be communicated to the Research Division of the International Labour Office for correlation.

2. That as photographic and photo-electric cell methods of dust determination have been successfully applied in certain special circumstances, there should be research in such methods, with a view to ascertaining their adaptability in other circumstances.

3. In view of the chemical theory of the causation of silicosis, the importance of estimating the size-frequency of particles has increased owing to the fact that the surface exposure (which varies greatly with different sized particles) is the chief factor in the amount of silica which goes into solution. It is suggested, therefore, that investigators should include in their work determinations of the size-frequency of particles.

4. (*a*) The Conference urges that the investigations suggested in paragraph 1 should be undertaken with the least possible delay in all countries which are interested in the problem.

In view of the thoroughness and outstanding work of research already carried out on the Witwatersrand, and in view of the special facilities which exist in that area, the Conference attaches special importance to the investigations which may be undertaken on the Witwatersrand and ventures to express the hope that they will be initiated at the earliest possible moment.

(*b*) The Conference recommends that as soon as the standard method referred to in paragraph 1 has been perfected it should be applied for the purpose of making at least one complete survey of the dust concentration in dusty industries throughout the world. The results of this survey should be communicated to the International Labour Office.

(*c*) The Conference considers that the survey recommended in (*b*) should include an investigation into the relative size-frequency of the dust particles.

Every effort should be made to emphasise the fact that the prevention of silicosis must be achieved by means of a whole series of provisions relating to hygiene in mines—*viz.*, chiefly by reducing production and diffusion of dust, by maintaining the purity of the air, and by means of personal hygiene.

5. That no opportunity should be lost of stressing the importance of general and localised ventilation as one of the best hygienic measures in dusty industries.

6. That the personal protection of the workers should not be exclusively confined to such protective measures as, for instance, the wearing of masks, but should be supplemented by secondary measures such as the provision of suitable change houses and shelters, and by the regulation of working hours, etc.

7. That many of the points raised in the prevention and control of dust call urgently for investigation by the physicists.

Etiology, Pathology, and Diagnostics

This discussion was opened by Dr. Mavrogordato, who said that any inert relatively insoluble dust which gets into the lungs in sufficient quantity favors fibrotic conditions. A dusty lung is a wounded lung and any infection is of great importance. He dealt with the advantage which might result from intermittent employment in a dusty trade, whereby the lungs could eliminate dust. Infection is essential if silicosis is to progress, and this infection is not only tuberculous.

"Can silica dust," he asked, "start an allergic state in the tissues akin to tubercle and might these two allergies bear some reciprocal reaction?" If a dry bronchiolitis were present, he thought that dust could more easily get into the lung. His observations have convinced him that silica aids the growth of tubercle bacilli—how, is unknown.

Dr. Gardner said that dust of granite, carborundum, aloxite, emery,

etc., placed in the peritoneal cavity of guinea-pigs is ingested by phagocytes which are not damaged, so that the preservative effect of dust on these cells is not confined, as thought by Dr. Mavrogordato, to silica. His experiments sought to determine whether the development of a silicosis in guinea-pigs would alter the virulence of superimposed tuberculous infection. He used an attenuated strain of Bacillus tuberculosis, which, by inhalation, produced only isolated subpleural tubercles in lung tissue, massive involvement in tracheobronchial lymph nodes, and nothing in other viscera—an infection which was cured by resolution within two years and which never killed the guinea-pig. He found that in infected animals dusted by daily inhalation of quartz, the tuberculous lesions spread and generally pulmonary tuberculosis — chronic and fatal — resulted. From further experiments he concluded that the virulence of the strain of tubercle used had not increased, but that a temporary alteration in environment had been produced in the silicated lung which favored multiplication of the tubercle bacilli.

Dr. Gardner stated that the rabbit was a better animal than the guinea-pig for experimental work, owing to the greater development of lymphoid tissue in the lungs of the rabbit, which caused a fuller reaction to dust inhalation.

Professor Loriga thought that silicosis was a pathologic entity not differing from other pneumonokonioses.

Pathology

Dr. Strachan said that from examination of cases of status lymphaticus, Dr. Simson and he had determined the distribution of lymphoid tissue in the lungs and found that it was related to the air passages—the dust cells accumulated in this lymph tissue round the smaller bronchi and bronchioles. A cellular fibroblastic reaction gives rise to a dense ball of hyaline fibrous tissue. The cellular fibroblastic lesions show first in the tracheobronchial glands, then in the pleura, and finally in the lung substance. As biologic tests of certain fibroblastic lesions had proved negative for Bacillus tuberculosis, he considered that there is a definite entity *simple silicosis*. To the type of silicosis in which infection plays a part the term *infective silicosis* can be applied; here the nodules have more exuberant fibrous tissue and are more rapid in growth, and central necrosis occurs early. In simple silicosis degenerative changes of nodules are fatty, sometimes with calcification; necrosis is rarely seen. Professor Kettle demonstrated microscopic preparations showing the modification of artificial miliary tuberculosis by silica. Rabbits inoculated first with intravenous amorphous silica and later with Bacillus tuberculosis develop more miliary tubercles than rabbits not receiving the silica injection. In mice with interstitial lesions produced by silica or calcium followed by tubercle bacilli intravenously, the tubercle bacilli were found in much greater number in the silica lesion than in the calcium lesion.

Dr. Gardner gave a lecture and demonstration of his very important work at the Trudeau Sanatorium at Saranac, which appears destined to guide our outlook on dust diseases in the immediate future. He described

an interesting technic for exposing animals to various dusts; his experiments were conducted on a large scale and continued over periods of more than two years. Setting out to determine whether development of silicosis alters the virulence of the bacilli of a superimposed tuberculous infection, he found that marble dust with less than 1 per cent. of free silica produced only hyperplasia of lymphoid tissue of the lungs of guinea-pigs. After two years' exposure, while the attenuated strain of tubercle bacilli did not develop a generalized tuberculosis, there was, nevertheless, a well-marked failure of the normal process of resolution in many of the tubercles with calcification of caseous centers. This effect was not due to the calcium of the marble for a similar thing was seen to follow carborundum dusting.

Granite dust is too slow in action to produce fibrosis of lung tissue in the exposure period possible in a guinea-pig. A true fibrosis is found in tracheobronchial lymph nodes after exposure for two or three years. Alveolar phagocytes which have ingested dust particles accumulate in the air spaces.

With carborundum dust no nodular fibrosis develops after four years except in the tracheobronchial lymph nodes. Masses of dust laden phagocytes accumulate in the alveoli. There are marked changes in the connective tissues of the bronchi and blood vessels which are thickened by vascular granulation tissue with lymphoid phagocytic cells.

With quartz dust the phagocytes instead of remaining for long periods in masses in the terminal bronchioles, as with granite and carborundum dusts, migrate and reach lymphoid tissue of the lung. A nodule is formed without fibrosis, perhaps similar to Dr. Mavrogordato's pseudotubercle. A cellular fibrosis replaces this nodule of phagocytes and there follows the characteristic hyaline appearance of the fully formed silicotic nodule as seen in human beings. A similar reaction occurs even earlier in the tracheobronchial lymph nodes.

The reaction of guinea-pigs to asbestos dust differs markedly from the reaction to the preceding dusts. Asbestos particles when inhaled come to rest on the irregular walls of the bronchioles. The phagocytes do not migrate to lymphoid tissues. Some of them find their way to the cells of air passages and the fibroblasts in the bronchioles proliferate to form a delicate fibrosis; this tissue contracting constricts the air spaces. But in rabbits, on the contrary, phagocytes do carry inhaled asbestos to lymphoid tissues.

Dr. Gardner concluded from his experiments that the difference in the localization of various dusts is a function of the action of these dusts upon phagocytes which have ingested them. He formulated a working hypothesis, *viz.*, that any dust possessing the necessary chemical composition will provoke fibrosis, when and where phagocytes are concentrated in sufficient quantities in contact with preexisting connective tissue cells.

Dr. Gardner's address and demonstration did not cover the large scope of his work. His extraordinarily interesting work on the reactivation of healing primary tubercles in the lung by the inhalation of quartz, granite, and carborundum dusts was barely touched upon.

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Diagnosis

The sixth sitting of the Conference was concerned with the diagnosis of silicosis as an industrial disease. Dr. Irvine dealt at length with this question. He urged the adoption of a standard of diagnosis of silicosis and thought that such a standard could be reached by correlation of pathologic, radiologic, and clinical results. This correlation has been done in Johannesburg. A satisfactory radiograph is the most reliable single criterion in diagnosis, but it should be considered along with a medical and an industrial history. He dealt with the development of the disease, defining a bronchial phase with generalized ramifying fibrosis followed by a nodular phase which is actually simple silicosis as at present defined. Only in a minority of cases of clinically definite simple silicosis is this the whole picture, for already in the majority of cases foci of tuberculosis are continually present. An infective phase, most commonly tuberculous, usually follows. Such cases in South Africa are called infective silicosis and not tuberculosis and silicosis unless "an active clinically detectable deteriorating tuberculosis is present." Dr. Irvine thought that as a general standard the radiograph should show indications of commencing nodules, but he would deviate from this definition and follow the example of the Miners' Phthisis Medical Bureau which recognized silicosis with only simple generalized arborization and no nodulation, if there were any infective element present and a mining history. He stressed the fact that the South African diagnosis of tuberculosis is on clinical and not on radiographic grounds. In routine work, disability is ascertained by common sense clinical methods. An Australian delegate drew attention to the fact that as cases of fibrosis of the lungs occurred resembling cases of silicosis found in South Africa, but originating from exposure to dust containing 85 per cent. of silicates, intractable or otherwise, with 15 per cent. of free silica, care was needed in making any standard for the diagnosis of silicosis apart from other dust fibroses.

Dr. Middleton spoke of varying types of dust fibroses resulting from the dust of different industries. In cotton and other textile workers there is a peribronchial type of fibrosis approximating the fibrotic picture obtained in workers with dusts having a low silica content.

Professor Böhme mentioned Edling's work among Swedish coal miners. The coal in which they work is soft and free from chemical impurities. The radiographs of these miners resembled the appearances seen in silicosis; pathologic examination of the lungs, however, shows no fibrosis, but only the filling up of alveoli and bronchioles with coal dust, and congestion of the tissues.

While Dr. Gardner thought that lymphatic obstruction played an important part in the production of fibrous diseases of the lungs, Dr. Strachan thought that lymph stasis played no part.

Professor Kettle queried the bronchiolitis brought forward by the South African pathologists as an early change in silicosis, and another delegate thought that this was a postmortem condition.

Dr. Mavrogordato urged a distinction and a definition of silicosis, separating it from other pneumonokonioses. He believed that lymph stasis played an important part in its production.

Dr. Irvine spoke further on general ramifying fibrosis as a distinct presilicotic phase. He said that the practical working rule was that if a man developed this non-nodular type of fibrosis after a long service underground and there was disability, they were inclined to compensate.

Professor Böhme, whose publication on silicosis in Germany was one of the most interesting before the Conference, gave a demonstration of a number of extraordinarily fine sections showing the pathologic conditions seen in lungs affected by dust and tuberculosis.

Dr. Moore said that physical tests and estimation of vital capacity had been of very little advantage in Western Australia and Tasmania. The radiographic appearances of men affected by asbestos were shown or described by Professor Loriga, Dr. Gardner, and Dr. Middleton. It was agreed that the appearance was that of a generalized fine fibrosis. The South African pathologists have examined the sputums of fifty asbestos workers and demonstrated the "curious bodies" in forty-eight.

Dr. Badham read a paper on the radiographic examination of certain Australian coal miners. This work was done in collaboration with Dr. Moore of the Commonwealth Health Department of Australia. A group of ten men who showed a fine type of pneumonokoniosis had been found by Dr. Badham to work in the same pit. It was desired to ascertain the incidence of pulmonary fibrosis among coal miners in this district chiefly because the practice of stone dusting to prevent explosions was being initiated. It was pointed out that such an investigation was essential to prevent future cases of fibrosis from being ascribed inaccurately to the practice of stone dusting, and to save this scientific safeguard from falling into disrepute. It appeared likely that certain of the stone dusts used could, after a sufficient period of exposure, cause fibrosis; nevertheless, the continual exposure of coal miners to the dusts of certain pits was considered to be more inimical and more difficult to control.

Of the 471 radiographs taken, seventy-seven were selected for submission to the Conference, all of which showed fibrotic changes in degrees varying from slight to dense fibrosis, with or without associated infection. Of these seventy-seven, thirty-five showed changes due to infective processes. Of the seventy-seven men who were diagnosed as having fibrosis, twenty-eight had a purely Australian coal mining history. The coal measures in which these men worked do not contain free silica, as far as can be determined, in amount greater than 1 per cent. The strata associated with the large seams which are worked consist of shale. An exposure to shale dust is very slight owing to the size of the seams worked.

Members of the Conference were very interested in these films and anxious to learn the pathologic condition of the lungs. The Australian delegates had no information on this essential point and the recent patho-

logic work of Collis and Goadby was not then available.

Finally, Professor Kettle drafted definitions of the stages of silicosis and it was agreed that tuberculosis should be regarded as an auxiliary entity to silicosis, a condition parallel to it and adding to the disability caused by it.

Dr. Orenstein secured from the Conference a statement that in the present state of our knowledge on the pathology of the diseases, the view was not considered justified, that silicosis is essentially tuberculosis, at least as seen in South Africa.

The reporters on the Section of Etiology, Pathology, and Diagnostics were Doctors Gardner, Middleton, Orenstein, and Steuart. Among their conclusions which were accepted by the Conference were Nos. 4, 7, 23 and 24, which dealt with dust diseases generally:

4. Silica dust plays the dominant rôle in the production of silicosis, admixture of other dusts tending to modify the picture in the direction of that of other pneumonokonioses, in some relation to the proportion of free silica inhaled.

7. The establishment of a silicotic process in a lung renders the subsequent inhalation of other dusts, in themselves relatively innocuous, capable of producing serious pneumonokoniosis.

23. The inhalation of asbestos dust produces a definite pneumonokoniosis, which may occur also in association with tuberculosis, and deaths have been recorded.

This pneumonokoniosis is associated with the presence in the lungs of "asbestosis bodies," but the mere presence of these bodies in the lungs or sputum does not constitute evidence of the disease.

For the diagnosis of this pneumonokoniosis the same criteria as described for silicosis should be applied, mutatis mutandis.

There is not at present sufficient evidence to show definitely to what extent tuberculosis and this type of pneumonokoniosis react upon one another.

24. There are other dusts, such as, for example, from marble, coal and carborundum, etc., which may contain small quantities of silica and produce demonstrable lung changes, radiographically resembling in some cases the appearances observed in early silicosis.

There is not sufficient body of evidence available to enable a definite statement to be made of pathological changes in man. In animal experiments, the inhalation of carborundum dust over a period of four years has produced fibrosis only in the tracheobronchial lymph nodes; the lungs were entirely free of fibrotic changes. This, and other observations on inhaled granite and asbestos dusts suggest the hypothesis that to produce pulmonary fibrosis a sufficient concentration of a relatively insoluble dust must be brought by the activity of phagocytic cells into intimate contact with connective tissues. With these dusts the migration of phagocytes, for at least a prolonged period, is ineffective in establishing such contact in the lung. Only in the tracheobronchial nodes are these conditions realised during a period of four years.

Silicosis in its limited sense was dealt with in many other conclusions which covered its pathology and radiographic appearance.

The Conference agreed, also, on conclusion No. 8 which stated:

8. It was suggested that intermittency of employment retards the onset of silicosis, but the evidence adduced in support of this, though suggestive, is not conclusive, when the total period of exposure is not affected.

Prognosis, Compensation, and After Care

The ninth session of the Conference was concerned with the subjects of Prognosis, Compensation, and After Care.

Mr. Spence Fraser stated that while it was true that the annual number of new cases of silicosis today was about the same as in 1920 to 1923, still he had no hesitation in saying that the position had improved. This optimism did not appear acceptable to all the South African delegates who were in a better position to appreciate the value of South African work than delegates from overseas. The apparent contradiction in the statement that the position had improved while the production rate of silicosis was the same was explained as due to the different type of miners employed, the percentage of long-service men being now much greater than previously. Dr. Orenstein was critical of the statistical deductions and Professor Hall urged that full data should be analyzed by overseas actuaries for the confirmation of South African views. Some delegates seemed to think that it was premature to speak of the good progress of the campaign against silicosis when the production rates and cost of compensation showed no abatement, and the latter was even increasing.

Dr. George of Broken Hill, New South Wales, said that in 1922 and 1923, thirty-four Broken Hill miners suffering from uncomplicated silicosis were settled on orchard farms. The men were told that they had no incapacity and that they would make a success of their new lives. These men were a specially selected group. From the commencement the scheme was a failure. Up to the present time, of these thirty-four men, seventeen have developed or died of pulmonary tuberculosis; about nine of these men are still on their farms, and some of them have definite tuberculosis. Dr. Pringle, of the Rand Miners Sanatorium at Springkell, said that men certified as silicotics could not do agricultural work.

The Chairman, Dr. Irvine, said that the number of silicotics who did not leave underground work was small. They progressed no worse than the men who left, but the majority were mine officials. The Miners' Phthisis Medical Bureau believed that about 25 per cent. of the men who continued underground work would be prejudicially affected.

Mr. Du Toit of the Miners' Phthisis Board showed that work in mines other than the Rand had put a load on the South African compensation scheme. He stressed the difficulties of rehabilitation, instancing the failure of land settlement of silicotics in South Africa and Australia.

Dr. Fisher thought that alternative employment was impossible for coal miners owing to social conditions. He suggested the employment of affected coal miners on repairs in main haulage roads at agreed rates.

Dr. Orenstein made a plea for the better use of the money spent in compensation. He raised the question as to whether we might consider silicosis preventable; certainly removal from work in early stages has not prevented further progress of the disease. He stated his belief that there were no good grounds for the compulsory removal of silicotics from their customary employment unless such removal did not tend to lower markedly their economic level of livelihood. He thought that the removal in the fifth and sixth decades of life was generally

inadvisable unless a high degree of incapacity was present.

The reporters of this section were Dr. Cunningham, Professor Hall, Professor Koelsch, and Dr. Badham (co-opted). Professor Hall drafted an account which summarized the discussions under four headings:

1. What is the prospect of a man exposed to free silica dust as regards acquiring silicosis?
2. What is the prognosis in a case of simple silicosis if he leaves the industry at the first stage of the disease (ante-primary stage)?
3. What is the prognosis in a case of simple silicosis if he remains in the industry after the first stage of the disease (ante-primary stage) declares itself?
4. What is the prognosis in a case of silicosis with tuberculosis?

His colleagues agreed with this presentation after certain alterations. While the original of this draft was a valuable guide to our present outlook, it was, nevertheless, adjudged to be too lengthy to secure more or less ready acceptance by the Conference. It is to be hoped that the original draft will be published in toto elsewhere. I will, however, quote part of the original draft of questions 2 and 3 in full:

Question 2.—What is the prognosis in a case of simple silicosis if he leaves the industry at the first stage of the disease (ante-primary stage)?

(*N. B.* Here and throughout this Report the term silicosis will be used according to the South African terminology as distinct from tuberculosis with silicosis. The question whether it is really a simple silicosis or whether it is an infective silicosis will be dealt with in particular instances.)

It was natural to hope and even to expect that by catching the silicotic at his earliest recognisable stage as is being done in the South African mines, and by removing him at once from the industry, the disease would be prevented from progressing, and if not actually checked would at least be arrested. Speaking generally, however, this sanguine expectation has not been fulfilled. With the exception of a comparatively small number, most of the cases leaving the industry on the first discovery of silicosis at the periodic medical examination progress unfavourably. This may be attributed to more than one cause. Some are of the so-called infective type—and that infection is in most cases believed to be of a peculiar latent tubercular nature—which though not coming under the legal definition of tuberculosis as laid down in the South African statute, and indeed having a somewhat obscure pathological history, is yet a serious hindrance to the arrest of progress of the disease even though the man be removed from the industry immediately.

This difficult and as yet not fully understood complication of the subject—namely, infective silicosis—is dealt with elsewhere in the report. It plays a very important part in the question of prognosis.

Question 3.—What is the prognosis in a case of simple silicosis if he remains in the industry after the first stage of the disease (ante-primary) declares itself?

As, owing to economic factors connected with compensation, only a very small number of the silicotics in South Africa do remain at work underground after the disease has declared itself, the evidence on this point is somewhat indefinite. It is stated, however, that there are at present about 150 men in this position, and it is said that their progress is no worse than that of those who have left the mines. Among these 150 are included a considerable number of higher officials whose duties do not now expose them considerably to dust and whose economic position remains as good as before.

The opinion was expressed at the Conference that to continue at work underground will not prejudice the man very markedly.

Finally the reporters agreed upon the following recommendations with regard to compensation and after care,

which were adopted, after certain accepted alterations, by the Conference.

Compensation from the Medical Point of View

1. Silicosis complicated or not by tuberculosis constitutes an occupational disease which may involve reduction of working capacity.

2. It should be left to competent authorities to decide in accordance with their particular conditions, whether other forms of pneumonokoniosis should be regarded as occupational diseases.

3. In establishing the amount of disability, account should be taken of the clinical and functional condition as a whole.

4. The determination of disability should be entrusted to an independent medical expert, or body of experts, possessed of the requisite clinical and technical knowledge and having at his or their disposal suitable apparatus for effecting the examination.

5. It is suggested that removal from all industrial occupations involving exposure to noxious dust should be enforced in all cases of open tuberculosis.

6. Where legislation provides for the compulsory removal from occupations involving exposure to silica dust of workers affected by silicosis, it is suggested that such compulsory removal should not necessarily be applied to workers who have been in the same industry for a period of not less than fifteen years and have reached the age of 45 years.

After Care

1. Sanatorium treatment should be provided for suitable cases.

2. Hitherto most of the rehabilitation schemes have been unsuccessful. Further investigation into this problem is urgently called for.

It must be remembered that these recommendations were agreed upon at a Conference of delegates of many countries. Their acceptance, in view of the many and varied local conditions, enhances their value.

J. I. H.
May, 1931

BOOK REVIEW

SILICOSIS. RECORDS OF THE INTERNATIONAL CONFERENCE HELD AT JOHANNESBURG, 13–27 AUGUST, 1930. International Labour Office, Studies and Reports, Series F (Industrial Hygiene) No. 13. Paper. Pp. 692. Geneva, 1930.

The International Labour Office at Geneva has done well to publish under one cover the proceedings of the Congress on Silicosis, which was held at Johannesburg in August, 1930, and also the series of excellent papers prepared for the Congress by experts on various aspects of the disease, especially in regard to its occurrence in the gold mines of South Africa. Several of these expert papers are excellently illustrated to demonstrate pathologic and radiographic findings. They commence with an historical review of the mining conditions on the Witwatersrand, in which the dust and ventilation problems of today are shown to be totally different from those prevailing at the beginning of the century, at which time silicosis, in the form of miners' phthisis, came to be recognized as unduly prevalent among the miners. The character of the dust arising from the matrix of the gold bearing reef is described; it consists largely of quartz pebbles bound together by a hard silicious matrix. Much of the dust which originates from mining processes, from drilling, from blasting, from shoveling and other manipulations, is composed of fine particles of uncombined silica. The story is told of how measures were adopted for preventing the formation of this dust, and for preventing miners from inhaling such dust as could not be suppressed. Simultaneous with such preventive measures, the incidence of the disease in the gold mines has been steadily falling. Its history and etiology are set out, together with a close study of its pathology, radiology, and symptomatology. The monographs dealing with this aspect of the disease must be looked upon as standards for reference.

Experts attending the Congress from different parts of the world made their contributions, and we find the position with regard to silicosis in the various states of the Commonwealth of Australia shortly but clearly described. In that part of the world, as in South Africa, it is mainly a disease of miners, although certain stonemasons are also concerned. In Canada the position as described also concerns miners, although here granite cutters are developing the disease. The picture painted for Germany is more diverse, since in that country, with its many industries, a variety of operatives are exposed to the inhalation of silica dust, such as grinders of metal, rock drillers, and pottery makers. In recent years the attention given to the subject has greatly increased. The most comprehensive description is that dealing with silicosis in Great Britain, where many and varied investigations have been carried out, and compensation is

now awarded in a large number of industries. Facts and figures are given, dealing with the refractories industry; grinding of metals; sandstone industry; granite industry; slate quarrying and dressing; coal mining; tin mining; the pottery industry, with its many processes and exposure to the dust of powdered flint; sand blasting; silica milling; scouring powders; flint crushing; flint knapping; and millstone dressing. This article is a model of compact reporting. The position of pneumonokonioses in Italy is set forth, with reference to the manufacture of cement, and the use of asbestos and slate, and exposure to dust of sulphur and marble, together with some exposure to silica dust in a few mines. Contributions appear also dealing with silicosis in the Netherlands and in the United States.

The volume closes with a description of the work of the Miners' Phthisis Medical Bureau, and the way in which medical supervision of native labor on the gold mines is carried out. Already the example set by the work of the Bureau, both in its initial and in its periodic examinations, is being copied in other countries of the world.—*E. L. Collis.*

J. I. H.
May, 1931